The Development Of Mathematical Models For Media Selection*

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Introduction

One of the most important promotional tools of modern marketing management is advertising. An advertiser buys space and time in an advertising media to tell prospective customers about his product, hoping to be persuasive to some extent and create or reinforce buyer preference for the company's product. The importance of advertising can be noted by the fact that American companies are spending $20 billion a year in advertising. The recent attention given to advertising activites in Thailand, especially on television indicates the importance of advertising in Thailand. Media selection models will soon become a point of attention to Thai businessmen.

The advertiser faces five major advertising decision problems:

1. Advertising Goal Decision. The advertiser must decide what the object of his advertising expenditure is before he undertakes any plan.

2. Creative Message and Copy. The advertiser must determine what he wants to say and how he wants to say it.

3. Media Decision. The advertiser must decide when the message is to be introduced to the public and which media is to be used.

4. Timing Decision. Timing is important to overcome the effects of memory loss and seasonal factors. The advertiser must also decide between plans of steady advertising, burst advertising or alternating advertising.

5. Expenditure Level. The advertiser must decide upon the appropriation for advertising which is suitable for each promotional plan.

The problem is how to select the most efficient set of magazines, television and radio programs, newspapers, billboards and other available media for the purpose of achieving the most efficient way of reaching his prospective customers. The area of media selection is one area in marketing management which is increasingly incorporating quantitative tools as aids in the decision process. There has

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been two different approaches in models that attempt to analyze media selection. The first approach tries to model the problem by making simplifying assumptions to reduce the media data to comparatively few parameters and then use a mathematical algorithm to determine an optimum media schedule. The second approach does not guarantee an optimum solution but tries to arrive at a "good" solution by using heuristics and simulation models to try out different alternatives.

Mathematical optimizing techniques

When mathematical models were first applied to solving marketing problems, optimization was emphasized. Many of the early studies in operations research/ management science literature sought to develop mathematical structures which guaranteed the best possible solution to problems, Some of these techniques include

1. Calculus Models
2. Linear Programming
3. Dynamic Programming
4. Iteration or Marginal Analysis

Non-optimizing techniques

Optimizing techniques were applied to media selections with little success. The problems encountered by researchers and practitioners were too complex for the use of simple model structures. The ability of large scale modern computers made it possible for researchers to study complex models, numerous computational routines and data banks. This has proven to be a useful approach to the solution of complex marketing problems. Heuristic programming and simulation have been used to "try out" different alternatives and various managerial "rules of thumb." These non-optimizing techniques are

1. Heuristic Programming
2. Simulation

This paper will attempt to review some of the work done in each of these areas and point out some of their weaknesses.

Calculus Models

One of the early examples using non-linear calculus models is a model by Magee[15]. Magee studied the effect of promotional efforts on sales by devicing a method to measure relative efficiency of distribution of promotion and potential gain in sales through better distribution. The model was applied to the coffee industry. He found that the expected reduction in business was fifty percent in the absence of promotional efforts.

Vidale and Wolfe[21] did an empirical study and was able to show:

(a) In the absense of promotion, sales tended to decrease because of product obsolescense, competing advertising etc. The fact was incorporated in their model by a factor called the Sales Decay Constant.

(b) After continuous increase in the advertising level, there comes a stage where a saturation level is reached. This Saturation Level depends not only on the product being promoted but also on the advertising media being used.

(c) The model incorporates a Sales Response Constant which is the sales generated per advertising dollar. This constant decreases as the saturation level is approached.

Using these three factors and calculus, the authors were able to derive a formula for advertising appropriations for each product in a multiproduct company.

The two models mentioned above are examples of some work done in the early and mid-fifties. Neither model took into consideration discounts offered by media, multiplicity of exposure to advertisements, and timing of advertisements and audience duplication. The assumptions used in the model were far too simplified to make the models realistic.

Linear Programming

In 1960 a simple, hypothetical media problem was formulated as a linear progarmming problem by Miller and Starr[16] Two years later, an advertising firm, Batten, Barton, Durstine and Osborne placed a full page advertisement in *Advertising Age* stating "Linear Programming showed one BBDSO client how to get $1.67 worth of effective advertising for every dollar in his budget."

In June 1962, Day[3] pointed out that media selection was a problem of maximizing the effectiveness of the advertising program subject to a series of constraints such as budget, characteristics of available media and other environmental conditions.

Engle and Warshaw[4] attempted to implement Day's suggestion in which they tried to maximize an objective function where the coefficients of the variables were the number of engineers reached per dollar and the constraints were both budgetary and the number of exposures per magazine per time period. They modified the objective function to include an effectiveness rating for every magazine considered. This was one of the first attempts to include qualitative factors due to different media and audiences.

Linear Programming approach contains several assumptions which limits the usefulness of these models. Some of the limitations are:

(a) The objective function is linear in the number of exposures. This implies that the value of five exposures to one person is the same as one exposure to five people. The theory of diminishing marginal returns lead us to believe that this assumption is often violated in the real world. The effect of the linearity assumption in the solution is that the most efficient medium for generating exposure will usually be bought until some upper limit is reached, then the next most efficient will be bought and so on.

This limitation has been recognized by several people who have proposed nonlinear models (Kotler[10], Brown and Warshaw[9]) by converting nonlinear programs into linear ones having separable objective functions. This approach also uncovered other problems which have not been overcome.

(b) A constant media cost is assumed, when in reality, discounts are available and the final cost of the advertising is dependent upon the amount purchased from anyone media.

(c) The timing of insertions over time is ignored in L.P. It is generally agreed that timing of insertions is important to the effectiveness of a promotional plan. Certain advertising campaigns are effective when heavily concentrated in one period while others may work best when repeated steadily. Godfrey[8] has tried to handle this problem by introducing aditional variables and constraints. The technique, however, has not been too successful and has seen little use.

(d) L.P. does not consider audience duplication. When an advertisement is made in several media, similar audiences will be exposed to the advertisement and there will be some audience duplication. Ignoring this fact could lead to an inefficient promotional campaign.

(e) The solution of L.P. allows variables to take on fractional values, whereas the number of insertions must always be an integer. Zangwill[22] proposes the handling of this problem with integer programming, but the algorithm developed at the present time is not capable of handling large sized problems encountered in media selection.

(f) Linear Programming models generally require poor or non-existent data.

An article by Bass and Lonsdale[1] published in the Journal of Marketing Research, May, 1966, suggested using different weighting systems to adjust for audience of the vehicle who are considered to be prospective customers only. They have a weighting scheme for the different degrees of receptivity of the audience called the exposure factor. The third type of weight is called the weighted exposure unit designed to give greater weight to vehicles whose audience in similar to the market distribution of potential customers. They applied this weighting scheme to problems with different combinations of constraints but were not too successful. Their conclusion was as follows:—

(1) Linear Models are crude devices to apply to the media selection problem. The linearity assumption itself is the source of much difficulty. Justifying an assumption of a linear response to advertising exposure on theoretical grounds would be difficult.

(2) It appears that attempts to impose meaningful restraints on the linear model would probably be unfruitful. Where only the budget restraint and operational

restraints on each vehicle are employed, the model is reduced to a simple cost per thousand model. The distribution structure makes it difficult to develop useful restraints which allocate exposures to market segments.

(3) Crude as these models are, they suggest possible avenues for examining alternatives. Models with non-linear response functions, although empirically demanding, would diminish most problems associated with the imposition of judgement restraints on the linear structure.

Dynamic Programming

Gensch[6] described dynamic programming as a useful technique if the problem can be limited so that the carry-over effects form one period to another can be expressed in terms of five or six variables at most. This is exactly the reason why dynamic programming has not had much success in the past in the area of media selection. The requirements on the computer memory for any realistic media selection problem are prohibitive. Even large and modern computers like the CDC 6600 are not capable of handling anything more than 30 or 40 decision points at a time.

The mathematics of a dynamic programming model are relatively straight forward and can easily be programmed for a computer. The objective function of the dynamic programming problem is to maximize

$$\sum_{i=1}^{n} R_i$$

Where R_i stands for the reward for the process in stage i of which we are trying to maximize the sum of, over n stages. The reward at any time is a function of the process state at stage i and the decision made at stage i,

The dynamic programming algorithm is a brute force technique that takes into account all possible combinations of decisions and then selects the best alternative. The idea is to select the best decision in the nth stage and then working backwards to select the best decision in the n-1th stage, taking into account the decision made in the nth stage.

Little and Lodish[12] applied this technique to media selection. They first divided the market into homogeneous segments which were defined to be mutually exclusive and were presumed to represent relevant groups with respect to sales potential and media usage. The media vehicles were limited to 15 magazines in one period. The model assumed that amount of sales was strictly a function of the number of exposures to an ad. Other variables that could have affected the sales decision, such as price, quality and competition were disregarded. The model was not capable of handling discounted cost structure of advertising media.

Some tricks are now being studied in areas of Production Management to enable dynamic programming to be used in more complex problems. The author has been working on a computer program with assistance of Professor J.F. Muth of Indiana University to reduce the large memory requirement required in dynamic Programming. Several untried tricks have been suggested by Bryson and Ho[2] but the results of these tricks have not been satisfactory applied to the problem of media selection at the present time. The Sweeping Method and the Flooding Method[1] presently being studied by the author requires that the objective function be quantifiable in fairly precise way which could be a problem in media selection. The idea behind the method is to search for the approximate optimum point by using a large grid and gradually searching a smaller area with reduced grid sizes. If the method succeeds, there could be a new wave of enthusiasm in the use of dynamic programming for media selection problems. It must be pointed out that even with any breakthrough, the size of the problem capable of being solved may still be too small for practical applications.

Iteration Models

The underlying concept of the iteration approach is to try to bring one media vehicle at a time into the solution. The media vehicle with the highest value is selected first. The list is then reexamined, and the media vehicle with the next highest value is selected. This process is repeated until enough media vehicles have been selected to exhaust the budget. In many cases the value of the remaining vehicles are recomputed after every selection taking into account duplication with media vehicles previously selected. The objective of this model is that successive solutions are reached, each one moving nearer to the optimum until the optimum is reached.

One of the better known iteration models is Young and Rubicon's High Assay Principle which is discussed in a paper by Moran[17]. The Mather model is a British model and was used exclusively for press planning[6]. A flow diagram of the High Assay Model is given below.

Gensch[7] and Schocker[19] Point out that iteration models have some limitations inherent in the model:

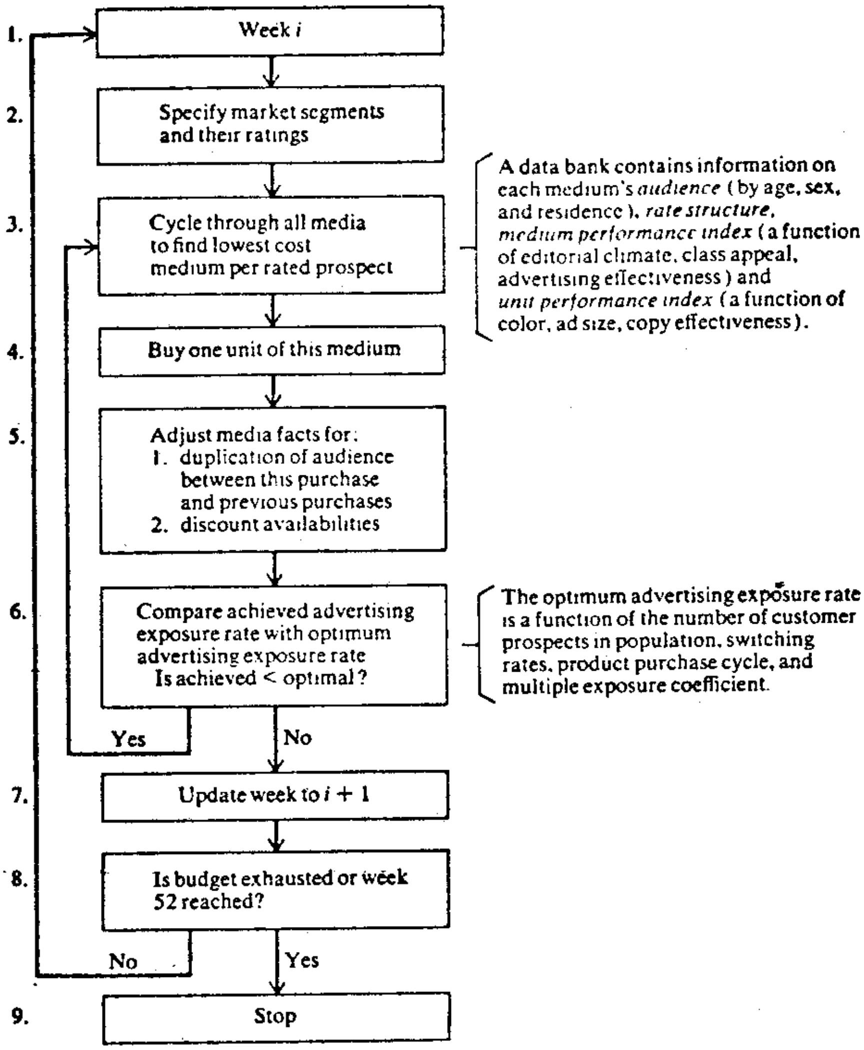
(1) The solution is not always optimal, especially when the surface of the function is characterized by several local optimums.

(2) The models do not specify the timing of the advertising.

(3) The models do not take into account the effect of advertising from past periods.

[1]See Bryson and Ho, pages 208, 217, 221, 231, for details.

High Assay Model



Source : Kotler "Marketing Decision Making" Holt, Rinehart & Winston, 1971, p, 457.

(4) The criterion function is too limited for a general Model.

(5) The models do not use integrated television and magazine data. Kotler[10] states that the high assay model represents an improvement over linear programming because it:

(1) Handles audience duplication problems.

(2) Handles media discount problems.

(3) Incorporates theoretically important variables such as brand switching rates and multiple exposure coefficients.

Heuristic Programming

Simon[20] referred to heuristics as a rule of thumb selected on the basis that they will aid in problem solving. Kuehn and Hamburger[11] defined a heuristic program to be a problem solving program organized around the device that contributes to the reduction in the average search to a solution. Its emphasis is on working towards optimum solution procedures rather than optimum solutions.

Three operation researchers, Lee, Burkart and Taylor, working for the British European Airways started work on a heuristic approach to scheduling advertising media in 1958. The airline was trying to get travellers to travel from London to Glasgow during the night flights for ecomonical reasons. The problem was that if the airline advertised the night flight too little, the return might be less than the advertising cost. However, too much advertising may generate too much traffic that an extra flight would be necessary which would destroy the economic basis of the whole program[6]

Little and Lodish[13] developed a simulation model using heuristics to solve for the "best" media schedule. This model has been revised many times. The last revision was done in 1971. This model has proved very useful to management training programs because it is programmed on a time sharing basis. The model will be described later as a simulation model.

The greatest advantage of heuristic paogramming is that it allows considerable flexibility in comprehending the complexities of the media selection model.

On the other hand, there are several limitations to heuristic programming:

(1) Heuristic approaches are non–optimizing.

(2) The existing models make use of simplistic assumptions, e. g., the expected response of a person to a campaign is determined by the number of insertions he sees.

(3) Heuristic programs that work perfectly well in one situation may be totally unsuitable in another. Usage of heuristic programs without the full understanding of the assumptions used to formulate the model could lead to undesirable results.

Simulation Models

Closely related to the heuristic models are the simulation models. This is the most comprehensive and detailed approach to analyzing the media selection problem. Simulation models are basically descriptive models, with the major emphasis on describing and replicating the real world. Once a model is considered to adequately describe reality, it can be made normative by the addition of heuristic rules[1].

Naylor[18] suggests that a simulation model should be tested to see if the internal logic structure is sound and to see if it could generate data to agree with actual past data. If these two tests are met, then our confidence that the model may actually represent the true situation will be increased. We, however, have no means of finding out whether the simulation model will actually behave as the real world problem we are trying to model.

Simulation allows sensitivity analysis to be made so that the model builder could study the effects of various media plans, which would give him a better idea of the possible success or failure under different situations. Replication of audience, forgetting, media interaction, cost discounts and non-linear response to media insertions can all be included into the model to improve realism.

The main problem with simulation models is that usage of the model without thorough understanding of the assumptions in the model may not help the advertiser a great deal. Another main criticism of computer simulation is that it does not provide an optimum solution. One defence against this criticism is that: the optimizing techniques assume that one can quantify the many relationships involved in the media selection process; if they can be put in mathematical terms at all, it is not likely that the derived function will provide more than a very crude semblance to the real world situation. Thus the 'optimal' solution provided by the optimization algorithm is only optimal if all of the assumptions used to quantify the relationships are relevant. Simulation also faces the problem of quantifying relationships that do not always lend themselves to quantification, but at least the problem is not compounded, but at least the problem is not compounded by the necessity to arrive at a function that fits into the relatively rigid framework of one of the optimizing techniques. Consequently its felt that simulation is the best of quantitative tools available.

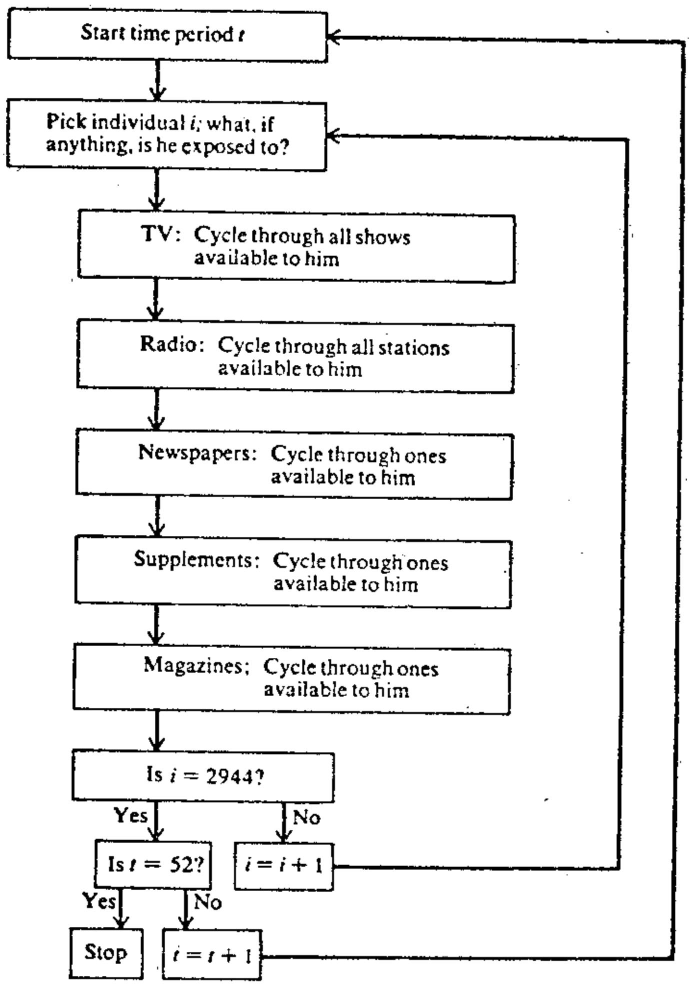
One of the most widely known simulation model is the Computer Assessment of Media (CAM) model of the London Press Exchange developed in 1954. CAM attempts to simulate the process by which television and magazine ads reach individuals, by first describing the steps in the communication process and then attaching numerical values to various stages. The model's objective is to describe how an advertising campaign affects the defined target population. The approach taken by the model is to combine all judgements involved in evaluating a media package into a logical flow sequence.

Another well known model is the Simulmatics Model developed by an American firm. The model generates its own imaginary population representing an accurate national sample. The computer tape contained detailed information on 2994 imaginary individuals, representing a cross sample of the U.S. population by sex, age, type of community, employment status, and education. Each individual's media choices are determine probabilistically as a function of his socioeconomic characieristics and location in one of ninety-eight American communities. A particular media schedule is exposed to all the persons in the population as shown below.

As the simulation year progresses, the computer tabulates the number and types of people being exposed by using a Monte Carlo routine. Summary graphs and tables are automatically prepared at the end of the hypothetical year's run. The advertiser examines the reports and decides whether the audience profile and reach and frequency characteristics of the proposed media schedule are satisfactory.

Another model which has been very successful in training advertising managers is the MEDIAC Model[13] This model is operational on a time sharing basis and gives immediate feedbeck to the programmer. The model considers market segment, sales potential, exposure probabilities, diminishing marginal respones rates, forgetting, seasonality, cost discounts and audience duplication.

Simulation Model



Source : Kotler "Marketing Decision Making" Holt, Rinehart & Winston, 1971, P. 459.

The Mediac Model is an allocation model which takes a fixed budget and spreads it over time and market segments. It does not perform as a budgeting model. The most important contribution of the model is the introduction of a relatively comprehensive problem structure. People often pick out one or two important issues of the problem and make their decisions by these issues. The model leads people to look at many issues and consider information from all of them.

Some of the main objections to this model are:

(a) The amount of data the user needs to supply. Many people claim that if they had all the needed data for the model, the best schedule would be obvious.

(b) The problem assumes a linear cost structure for the media,

(c) The exposure value is treated as a constant for the segment and multiplied against the number of exposures rather than having the exposure values decrease with duplication of exposure.

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This model puts quite a bit of emphasis on time in the assessment. It forcuses on the print media and goes as far as issue exposure in analysing a schedule. This model simulates a person's reading over time based on model of individual behavior and a Monte Carlo process. The basic data come from a survey of 2,000 individuals.

The model has two major improvements over the CAM and Simulamtics Models:

(1) The model introduced the timing of the ads into the decision process.

(2) It proposes using a panel to serve as a check on the predicted reading habits.

Conclusion

This article has attempted to review the literature and describe some of the mathematical tools used in media selection. Quantitative techniques can be of great benefit as an aid in decision making to the user when he understands the assumptions and limitations of the model. Two approaches were described:

(a) Mathematical optimizing approach

(b) Mathematical non-optimizing techniques.

The optimizing approach arrives at the best solution given the assumptions of the model. They are normally simpler to understand but some of the assumptions may be suspect which may in turn cause the derived functions to be very crude semblance of the real world situation. The "optimum" solution may turn out to be less than adequate solution. Optimizing techniques are normally more economic to model than the non-optimizing techniques and therefore may be more suitable for small advertisers.

The non-optimizing techniques seem to be more promising than their counterpart. With larger and more modern computers, simulation models have been more and more realistic. There, however, is a point where too much realism build into the model makes the model uneconomical in conputing time costs. Simulation allows the manager to "try out" different plans and evaluate those plans before actually implementing them. Time sharing models such as the Mediac Model has allowed smaller advertisers to use the simulation that are tailored closes to their needs. Larger corporations are capable of building models for their specific purposes and using them with more confidence of their applicability.

These models have not had much application in business in Thailand. It is likely that such models will be developed and specific information needed for media selection will be collected due to the ever increasing importance of advertising in Thailand. Market research agencies such as Deemar have been collecting television viewers and radio listeners statistics for several years. Such data may act as an input to some of the models presented earlier.

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